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Original article

Acceptance and commitment therapy for nurses' sleep, rumination, psychological flexibility, and it's neural mechanism: A randomized controlled fNIRS study

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ABSTRACT

Background: Given nurses often face sleep problems, this study compares two internet-delivered Acceptance and Commitment Therapy (ACT) interventions to improve sleep quality (SQ), psychological flexibility (PF), reduce rumination, and explore neural mechanisms. *Methods:* 477 nurses were randomly assigned to ACT linear psychotherapy model (LINEAR), ACT loop psychotherapy model (LOOP) and wait-list group. SQ, rumination, and PF were assessed with questionnaires. Prefrontal cortical activation changes were measured using functional near-infrared spectroscopy. *Results:* The linear mixed-effects model demonstrated significant improvements in SQ, PF, and reduced rumination compared to pre-intervention for both models through enhanced psychological flexibility. LOOP showed a significantly superior effect compared to LINEAR. DLPFC activation increased following both interventions, with LOOP additionally stimulating the frontopolar area. Changes in the DLPFC mediated the relationship between intervention and outcome improvements. Frontopolar changes mediated SQ improvements but not rumination or PF. No significant changes in functional connectivity were observed during the verbal fluency task. *Conclusions:* Both interventions improved outcome variables, with LOOP being notably more effective, offering a novel approach. Mediation analyses highlight the role of DLPFC activation in understanding ACT's mechanisms and targeting insomnia treatment, while the mechanisms of LOOP's superior effect warrant further research. *Trial Registration:* Chinese Clinical Trial Registry (ChiCTR2200063533). https://www.chictr.org.cn/

Introduction

Nurses, the largest healthcare group, are crucial in supporting doctors during treatment and recovery (Althobaity & Alshammari, 2020). However, factors like rising infection rates, heavy workloads, inadequate protective gear, demanding shifts, and bed shortages increase the risk of sleep problems among nurses (Firew et al., 2020; Zhang et al., 2021), with 42.9 % reporting poor sleep quality (Han et al., 2016). Prolonged sleep deprivation can lead to cognitive impairments and other serious issues (Mieda & Sakurai, 2013; Rosado et al., 2015). Therefore, improving nurses' sleep is essential.

Rumination is central to widely accepted insomnia models (Harvey,

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2002; Morin, 1993; Spielman et al., 1987) and the transdiagnostic model of insomnia (Harvey et al., 2005). According to the response styles theory (Nolen-Hoeksema, 1991), dwelling on stressful events and their consequences (i.e., rumination) prolongs and intensifies distress, leading to hyperarousal and difficulty sleeping (Brosschot et al., 2006; Guastella & Moulds, 2007). Rumination not only predicts insomnia, impaired subjective and objective sleep quality (Frøjd et al., 2022; Pillai et al., 2014; Winzeler et al., 2014), but also serves as a significant factor in perpetuating insomnia (Ballesio et al., 2021). Therefore, addressing rumination holds promise for improving sleep among nurses (Kurebayashi, 2020).

While cognitive and behavioral therapy for insomnia (CBT-I) is empirically supported, it faces adherence challenges, including withdrawal due to difficulties with stimulus control and sleep restriction techniques (Bouchard et al., 2003). Some patients do not experience significant improvements or continue to have sleep disturbances post CBT-I (Geiger-Brown et al., 2015; Ong & Smith, 2017). Acceptance and Commitment Therapy (ACT) emerges as a promising alternative to CBT-I (Martin et al., 2023; Shin et al., 2023), potentially addressing adherence issues and premature discontinuation (Martin et al., 2023; Saldaña et al., 2023), and improving various aspects of sleep (Paivi et al., 2019). According to the sleep effort model, excessive control and effort to sleep can hinder the natural sleep process (Broomfield & Espie, 2005). Unlike CBT-I, ACT prioritizes acceptance over modifying thoughts (Salari et al., 2020), promoting acceptance of insomnia and reducing excessive control (Shin et al., 2023). This approach can alleviate symptoms, increase sleepiness (Dalrymple et al., 2010), and demonstrate sustained intervention effectiveness (Vendela et al., 2018). Additionally, enhancing psychological flexibility (PF), the primary goal of ACT (Hayes et al., 2006, 2012), is significantly associated with improved sleep outcomes post-ACT (Daly-Eichenhardt et al., 2016; Zakiei et al., 2021) and better sleep quality (Wang et al., 2023). Given that nurses reportedly have lower PF (Duarte & Pinto-Gouveia, 2017; Wang et al., 2023), ACT's emphasis on enhancing this trait is particularly relevant. Therefore, ACT may offer a useful addition to CBT-I. Moreover, this study also targets reducing rumination. ACT has demonstrated promise in reducing both rumination (Kocovski et al., 2009) and repetitive thinking (Ruiz et al., 2018), emphasizing heightened awareness and present-focused mindfulness to foster acceptance, which effectively reduces rumination (Reyes et al., 2020; Shahkaram et al., 2024). Together, ACT is chosen as the foundation of our intervention protocol.

Furthermore, nurses' irregular schedules, including long night shifts, make traditional face-to-face interventions challenging to implement (Brunet et al., 2020; Feng et al., 2021). Internet- delivered interventions offer flexibility and have proven effective in improving sleep and well-being among shift workers (Newby et al., 2021; Peter et al., 2019). Given the high workload, limited rest time, and low salary of many nurses in China (Ye et al., 2020), these interventions are cost-effective, eliminating travel time and costs (Hedman et al., 2013). Therefore, nurses could benefit significantly from Internet-delivered interventions.

Our study developed two internet-delivered ACT (iACT) protocols: iACT loop (LOOP) and iACT linear (LINEAR) models. Both incorporate core ACT processes, including the six facets of psychological flexibility (PF) and inflexibility (PI) (Hayes et al., 2006) and daily mindfulness practices (Philip & Cherian, 2022). Each model consists of 6 lessons, supported by research on the feasibility of brief six-session ACT (Jäger et al., 2021). Despite these similarities, LINEAR and LOOP differ notably. LINEAR adopts a sequential structure, addressing one facet of PF and PI per lesson, providing structured support. LOOP, culturally adapted and inspired by ancient Chinese Daoism, uses the four steps of "启-承-转-合(means starting- proceeding-transforming-integrating)"to explain the entire process of PF and PI per lesson. This allows participants to prioritize their most inflexible facet first, exploring internal solutions and cultivating flexibility through a recurring process. While LINEAR follows a fixed sequence, LOOP offers a more adaptive therapeutic journey.

Moreover, insomnia is associated with cerebral cortical dysfunction, with reduced prefrontal activation during tasks and decreased dorsolateral prefrontal cortex (DLPFC) recruitment during cognitive control (Sun et al., 2017; Wu et al., 2020). EEG, fNIRS, and fMRI studies highlight the prefrontal cortex's (PFC) pivotal role in sleep maintenance and regulation (Altena et al., 2008; Csipo et al., 2021; Leerssen et al., 2020; Massimini et al., 2004; Wu et al., 2020). Meanwhile, few studies have explored ACT's neural impact on sleep, primarily focusing on chronic pain Lee et al. (2023). While some found increased PFC activation post-ACT intervention among fibromyalgia patients (Jensen et al., 2012) and obsessive-compulsive disorders (Lee et al., 2023), others reported decreased activation in various brain regions (Aytur et al., 2021). Despite these findings, there is a lack of well-controlled studies investigating ACT's neural mechanisms, particularly in individuals with sleep problems. This study aims to fill this gap by examining the neural effects of ACT in nurses with poor sleep quality.

The verbal fluency task (VFT) is widely used to assess PFC activation and cognitive performance (Liu et al., 2020; Wewege et al., 2017). fNIRS, a safe and non-invasive neuroimaging technique, measures changes in brain hemodynamic responses (Sanders et al., 2019), providing insights into brain energy demand (Herold et al., 2018). With superior spatial resolution to EEG and enhanced temporal resolution compared to fMRI (Pinti et al., 2020). In this study, we use the fNIRS-VFT paradigm to induce cortical brain activation.

We hypothesize that both LOOP and LINEAR will effectively reduce rumination and improve sleep quality (SQ) and PF. Furthermore, we anticipate differences in intervention efficacy between LOOP and LINEAR. Additionally, we expect both models to induce changes in prefrontal cortex activation.

Method

Design

This was a single center double-blinded randomized controlled trial. It received approval from the Institutional Review Board of the Medical Ethics Committee of the first author's affiliation (Approval No of Ethics Committee: S2021–568–01) and was pre-registered at the Chinese Clinical Trials Registry (ChiCTR2200063533) following RCT guidelines. The study adhered to ethical standards outlined in the Helsinki Declaration of 1975, as revised in 2008.

Participants

Participants from Beijing Class 3A Comprehensive Hospital were recruited through online WeChat ads promoting a novel psychotherapy model aimed at improving sleep, psychological flexibility, and reducing rumination. Interested nurses joined via a WeChat Mini Program (see supplementary Fig. S1) and completed an online screening questionnaire. Recruitment began in September 2022.

Inclusion criteria: (1) ages 19 to 65; (2) access to the internet, understanding instructions in Chinese; (3) Pittsburgh Sleep Quality Index score above 5, indicating poor sleep quality (Buysse et al., 1989; Patel et al., 2018); (4) right-handed. Exclusion criteria: (1) organic mental disorder, schizophrenia, or mood disorder; (2) visual or hearing impairment; (3) drug or alcohol dependence; and (4) prior ACT intervention experience. The psychiatrist and clinical psychology team from the hospital used the Structured Clinical Interview for DSM-5 Disorders (American Psychiatric Association, 2013) to assess exclusion criteria. Participants meeting these criteria were informed of their results and instructed to contact counseling services. All personal information and screening results were kept strictly confidential, and participants provided informed consent.

Procedures and randomization

Among the 734 nurses who responded to online ads, 257 were excluded based on criteria. Subsequently, 477 participants were randomly assigned to the LINEAR psychotherapy intervention group ($n = 159$), LOOP psychotherapy intervention group ($n = 159$), and control group ($n = 159$) at a 1:1:1 ratio (see Fig. 1). Randomization, conducted by an independent person using computer-generated pseudo-random numbers, ensured allocation concealment. All participants completed pre-intervention measurements (T1). The two intervention groups received distinct online self-help interventions, while the control group waited for one month. Post-intervention questionnaires were administered (T2), and 13 participants in the LINEAR group, 10 in the LOOP group, and 29 in the control group did not complete the intervention and post-intervention. Thus, the final post-intervention participant count was 425.

At trial inception, all the participants were offered the opportunity of undergoing fNIRS. After the enrollment of the first 80 participants, we estimated the proportion of individuals in each group willing to undergo fNIRS. A nonrandom subgroup of participants was then selected to undergo fNIRS to achieve the target sample size of 240 (approximately half the enrolled participants) (Barnes et al., 2023). fNIRS scans were conducted during both pre-intervention and post-intervention phases. These scans were administered by trained researchers who were unaware of the trial-group assignments.

Intervention

The one-month self-help online interventions (Table 1; supplementary Table S1 for detailed protocol) were delivered via the internet. The intervention for LINEAR group was based on the ACT LINEAR psychotherapy model, consisting of six online lessons delivered every five days in a fixed order, following the six facets of ACT. The content, provided through text, video, audio, and illustrations, required participants to practice Mindfulness daily for 20–30 min over 30 days to enhance present-moment awareness. Participants accessed one lesson at a time, progressing to the next lesson upon completion.

The intervention for LOOP group was based on the ACT LOOP psychotherapy model (Table 1; supplementary Table S2 for detailed protocol). Notably, the LOOP model is culturally adapted. Cultural adaptation involves the systematic modification of an evidence-based treatment to consider language, culture, and context, ensuring

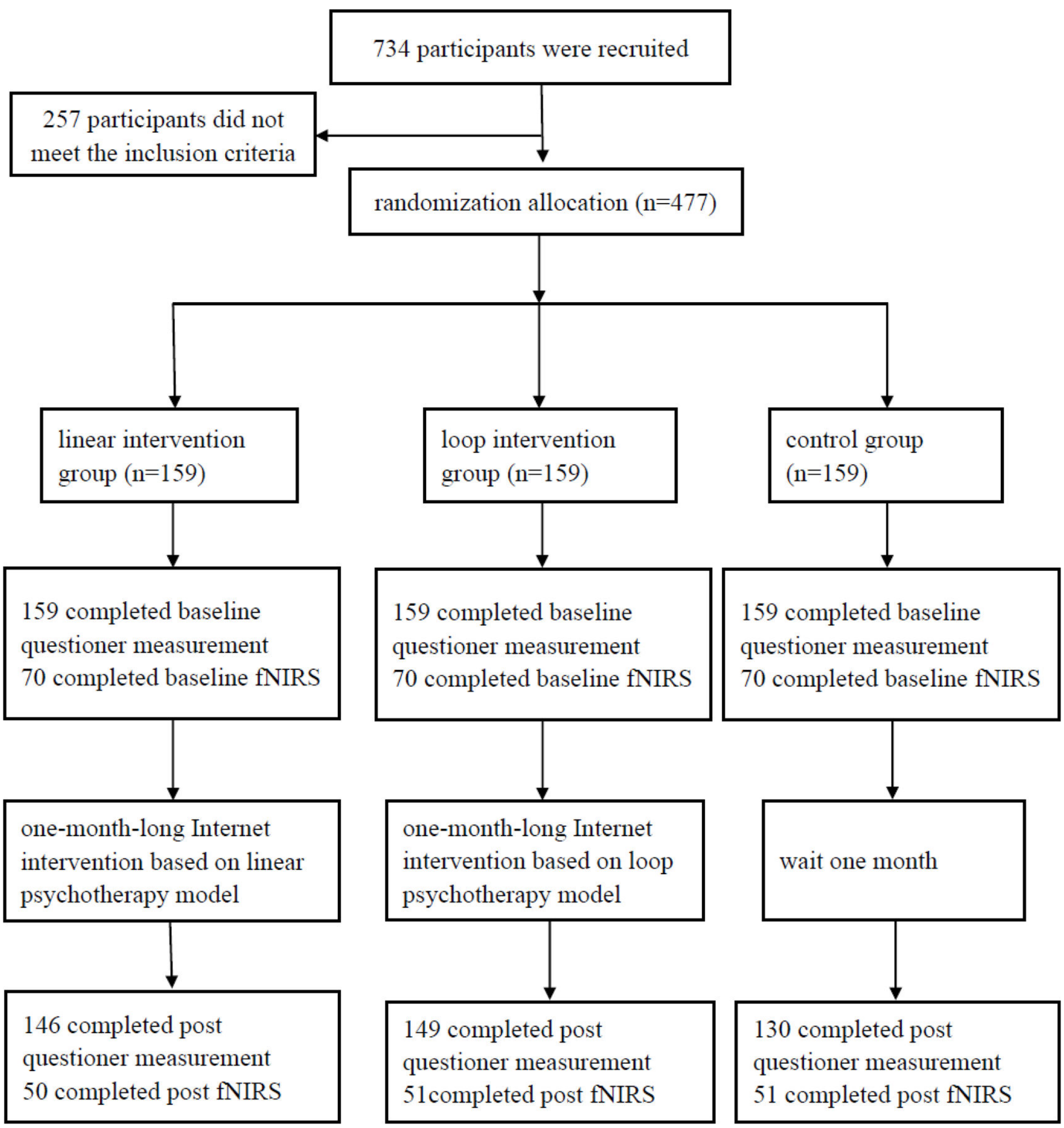


Fig. 1. Flow diagram of study design.

Table 1
Overview of iACT intervention content.

Linear psychotherapy protocol	Loop psychotherapy model	Daily Mindfulness Practice (Homework)
lesson 1: Experiential Avoidance and Acceptance. Lecture and explain what is Experiential Avoidance and Acceptance, and how to apply Acceptance to life. **lesson 2: Cognitive Fusion and Defusion.** Lecture and explain what is Cognitive Fusion and Defusion, and how to apply Defusion to life. **lesson 3: Dominance of the Conceptualized Past and Feared Future, and Contact with the Present Moment.** Lecture and explain what the Dominance of the Conceptualized Past and Feared Future is, Contact with the Present Moment, and how to Contact with the Present Moment. **lesson 4: Attachment to the Conceptualized Self and Self as Context.** Lecture and explain what is Attachment to the Conceptualized Self and Self as Context, and how to achieve Self as Context. **lesson 5: Lack of Values and Values** Lecture and explain what is Lack of Values and Values is and how to clear values. **lesson 6: Inaction and Committed Action.** Lecture and explain what is Inaction and Committed Action, and how to commit to action.	**lesson 1: Psychological flexibility and psychological inflexibility.** Firstly, let the participants set a goal to achieve after this lesson. Secondly, guide them to think about their past coping styles, and the consequences. Thirdly, Lecture and explain the whole six facets of psychological flexibility and psychological inflexibility, and how to apply them to life. Fourthly, let them choose and use the one facet of PF that is most suitable for them in the following 5 days. **lesson 2–6: Psychological flexibility and psychological inflexibility reinforcement.** Following the four steps, different examples, text, video, audio, and illustrations were used to illustrate the six facets, which provides the participants with a solution from the first lesson. Each lesson is a further explanation of the six facets, step by step, which gives participants more autonomy to start with the most inflexible facet, then guides them to explore their internal resources to proceed with the whole process.	Day 1–5: Body Scan in Mindfulness. Day 6–10: Body Stretch in Mindfulness. Day 11–15: Mindful Breathing. Day 15–20: Mindful Walking. Day 21–25: Metta Meditation in Mindfulness. Day 25–30: Breathing Space: the Door to Actions in Mindfulness.

compatibility with the client's cultural patterns, meanings, and values (Bernal et al., 2009). This includes integrating cultural factors such as interdependence and spirituality (Nagayama Hall et al., 2011). Our LOOP model, inspired by ancient Chinese Daoism principles that align with the spirit of constantly changing thinking patterns, use the four steps of "启-承-转-合(starting-proceeding-transforming-integrating)" to present content through text, video, audio, and illustrations, encouraging participants to select the suitable dimension based on different situations (Fig. 2). The six facets of psychological flexibility and inflexibility were introduced in the first lesson. Subsequent lessons illustrated these facets with examples, progressing from straightforward to more sophisticated. Participants identified their issues related to the six facets of psychological inflexibility and chose the appropriate facet of psychological flexibility to practice over the next five days. Like the LINEAR group, the LOOP group practiced daily Mindfulness for 20–30 min over 30 days. Participants accessed one lesson at a time and proceeded to the next lesson upon completion.

The control group did not receive any intervention and waited one month after completing the pre-intervention measurement.

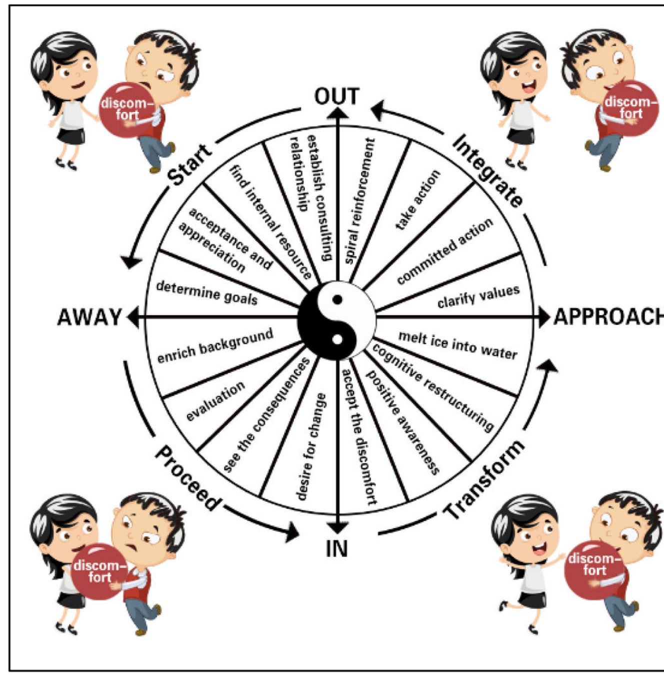


Fig. 2. Starting-Proceeding-Transforming-Integrating.

Outcome measures

Sleep quality

The Chinese version of Pittsburgh Sleep Quality Index (PSQI), translated by Liu (1996) from the original English version (Buysse et al., 1989), assesses participants' sleep quality. It shows high reliability and validity (Yan et al., 2021), with 18 items scored from 0 to 3. Higher scores indicate poorer sleep quality (T1Cronbach's $\alpha = 0.86$, T2Cronbach's $\alpha = 0.83$).

Rumination

The Chinese version of Ruminative Response Scale (RRS), translated by Yang (2009) from the original English version (Nolen-Hoeksema & Morrow, 1991), measures participants' level of rumination. It exhibits strong reliability and validity (Han & Yang, 2009), with 22 items graded from 1 (never) to 4 (always). Higher scores indicate higher levels of rumination (T1Cronbach's $\alpha = 0.89$, T2Cronbach's $\alpha = 0.83$).

Psychological flexibility

The Chinese version of the Multidimensional Psychological Flexibility Inventory (MPFI), translated by Lin (2020) from the original English version (Rolffs et al., 2018), includes two subscales: psychological flexibility and psychological inflexibility. Its internal consistency in Mandarin was excellent (Lin et al., 2020). With 60 items graded from 1 to 6, each subscale covers six dimensions, reflecting psychological flexibility or inflexibility. This study focused on the psychological flexibility subscale, where higher scores indicate greater psychological flexibility (T1Cronbach's $\alpha = 0.78$, T2Cronbach's $\alpha = 0.86$).

Verbal fluency task

A Chinese version of the Verbal Fluency Task (VFT) was conducted during daylight hours, consisting of a 30-second pre-task baseline, a 60-second task period, and a 60-second post-task baseline. Participants counted from 1 to 5 during both baseline periods and generated phrases using three Chinese characters in the task period, with characters changed every 20 s to minimize silent periods.

fNIRS measurement

Participants sat in a quiet room while a multi-channel continuous-wave near-infrared spectrometer (NirSmart-6000A, Danyang Huichuang Medical Equipment Co., Ltd., China) recorded changes in oxygenated hemoglobin (HbO) and deoxyhemoglobin (HbR) concentrations during the VFT to infer brain activity. The system used LED light sources and avalanche photodiodes (APD) at 730 nm and 850 nm wavelengths, with a sampling rate of 11 Hz. 14 source-detector (SD) probes with a fixed 3-cm inter-probe distance were arranged around the FPz channel (10/20 international system), covering bilateral prefrontal and temporal cortices, the lowest probes along the Fp1-Fp2 line (see supplementary Fig. S2). This established a total of 19 NIRS channels, with the channels and corresponding brain regions presented in supplementary Table S3. Oxy-Hb signals, known for their higher signal-to-noise ratio (Strangman et al., 2002) and retest reliability (Plichta et al., 2006), were employed as markers of regional cortical activity in this study.

Preprocessing included motion artifacts correction using moving SD and cubic spline interpolation, and a bandpass filter (0.01–0.20 Hz) to remove physiological noise. The modified Beer-Lambert law converted optical densities into changes in Oxy-Hb and Deoxy-Hb concentrations. VFT block waveforms were calculated with a block range set of 0–125 s, a pre-baseline range set of 0–10 s, and a post-baseline range set of 70–125s. We used a 60 s task period of constructing phrases as the time window to analyze mean Oxy-Hb changes. Linear fitting was applied to the data between these two baselines.

Statistical analyses

To account for variations within individuals in a longitudinally repeated study, we built a Linear Mixed-effects Model using the lme4 and lmerTest package in R. Fixed effects consisted of time effect, group effect, and their interaction, with random effects accounting for individual differences (Voldsbekk et al., 2021). This approach allowed us to assess the impact of timeframes (pre- and post-intervention) and different groups on changes in outcome variables. The value β in the mixed-effects model represented the estimated effect. Pairwise comparisons of estimated marginal means among treatments were made for each group using the emmeans package (Lenth, 2024). Statistical significance set at $p < 0.05$.

Mediation models were tested using Process 3.5 (Hayes & Preacher, 2014). We first examined the mediating effect of PF changes on outcome changes for LOOP versus control and LINEAR versus control. Next, we assessed LOOP's superior efficacy by testing the mediating effect of PF changes for LOOP versus LINEAR. We then explored the neural mechanism of ACT by analyzing the mediating effect of brain activation changes on outcome changes for both LOOP versus control and LINEAR versus control, as well as comparing LOOP with LINEAR to further clarify LOOP's superior efficacy. Both direct and indirect effects were assessed, using bootstrapping with 5000 resamples and 95 % confidence intervals, fully adjusted for covariates. The indirect effect was deemed significant if 0 was not included in the confidence interval.

Intention-to-treat (ITT) analysis was employed, and missing values were imputed using the last observation carried forward method. Descriptive statistics were used for between-group differences at baseline. Categorical variables, such as gender, employment, and other demographics, were analyzed using the chi-square test (χ^2), while continuous variables, such as age and outcome measures, were analyzed using one-way ANOVA for comparisons among three groups and independent-sample T-test for comparisons between two groups.

Results

Demographics and baseline data

As presented in Table 2, participants in the three groups did not exhibit significant differences in demographics and outcome variables prior to the intervention.

Table 2
Demographics and baseline data.

	Linear intervention Group ($n = 159$)	Loop intervention Group ($n = 159$)	Control Group ($n = 159$)	χ^2 or *F* (*p*)
Age — yr				0.29 (0.75)
M±*SD*	27.36 ± 6.45	27.14 ± 5.87	26.84 ± 6.64	
Range	18 - 46	18 - 39	18 - 49	
Sex, n (%)				1.68 (0.43)
Male	9 (5.70 %)	9 (5.70 %)	14 (8.80 %)	
Female	150 (94.30 %)	150 (94.30 %)	145 (91.20 %)	
Employment, n (%)				0.42 (0.81)
Employed	139 (87.40 %)	135 (84.90 %)	137 (86.20 %)	
Further education or internship	20 (12.60 %)	24 (15.10 %)	22 (13.80 %)	
Only child, n (%)				1.45 (0.48)
Yes	28 (17.60 %)	36 (22.60 %)	35 (22 %)	
No	131 (82.40 %)	123 (77.40 %)	124 (78 %)	
Having children, n (%)				3.54 (0.17)
Yes	66 (41.50 %)	64 (40.30 %)	51 (32.10 %)	
No	93 (58.50 %)	95 (59.70 %)	108 (67.90 %)	
Marital status, n (%)				1.59 (0.45)
Married	68 (42.80 %)	75 (47.20 %)	64 (40.30 %)	
Unmarried	91 (57.20 %)	84 (52.80 %)	95 (59.70 %)	
Years of working, n (%)				3.95 (0.41)
1–10 years	100 (62.90 %)	99 (62.30 %)	113 (71.10 %)	
11–15 years	40 (25.20 %)	37 (23.30 %)	29 (18.20 %)	
over 15 years	19 (11.90 %)	23(14.50 %)	17 (10.70 %)	
PF score, (M ±*SD*)	74.67±13.73	73.75±12.48	72.93 ±13.40	0.69 (0.50)
RRS score, (M ±*SD*)	48.42±10.64	46.84±11.15	46.72 ±10.61	1.22 (0.30)
SQ score, (M ±*SD*)	10.03±3.04	9.43±3.04	9.59±3.10	1.39 (0.25)

Notes. PF = Psychological Flexibility; RRS = Rumination; SQ = Sleep quality.

iACT interventions on psychological flexibility, rumination, and sleep quality

The linear mixed effect model examined the effects of linear psychotherapy model (LINEAR) and loop psychotherapy model (LOOP) on PF, rumination and SQ.

As shown in Table 3. For PF, time effect showed no statistically significant differences between pre- and post-intervention means across the control group [β (95 %CI): 1.830 (−0.548, 4.208), $p = 0.133$]. Group effect was not significantly different between intervention and control means at baseline [LINEAR-CON: β (95 %CI): 1.736 (−1.516, 4.987), $p = 0.297$; LOOP-CON: 0.824 (−2.428, 4.075), $p = 0.620$]. Group * time estimated the difference in mean change from pre-to post-intervention for LINEAR and LOOP compared to control group. Our results demonstrated that LINEAR and LOOP could significantly improve PF [LINEAR:

Table 3
Effects of iACT on psychological flexibility, rumination and sleep quality.

	SQ			PF			RRS		
	β	Lower 95 CI	Upper 95 CI	β	Lower 95 CI	Upper 95 CI	β	Lower 95 CI	Upper 95 CI
Time points	−0.465	−1.027	0.096	1.830	−0.548	4.208	−1.579	−3.547	0.390
LINEAR-CON	0.346	−0.290	0.982	1.736	−1.516	4.987	1.591	−0.489	3.671
LOOP-CON	−0.201	−0.837	0.434	0.824	−2.428	4.075	0.780	−1.301	2.860
LINEAR-CON: Time points	−3.730	−4.523	−2.936	21.296	17.932	24.659	−13.170	−15.954	−10.386
LOOP-CON: Time points	−4.340	−5.133	−3.546	34.723	31.360	38.087	−13.849	−16.633	−11.065

Notes. 95 % CI = 95 % confidence intervals; CON = control group; LINEAR = linear intervention group; LOOP = loop intervention group; PF, Psychological Flexibility score; RRS = Rumination score; SQ = Sleep quality score.

β (95 %CI): 21.296 (17.932, 24.659), $p < 0.001$; LOOP: −4.340 (−5.133, −3.546), $p < 0.001$]. As shown in Supplementary Table S4, LINEAR and LOOP differed significantly post-intervention ($p < 0.001$). The LOOP [Emmeans = 110.3 (108.0–112.6)] had a better effect on increasing PF compared to the LINEAR [Emmeans = 97.8 (95.5–100.1)].

For rumination, group * time estimated mean change differences between LINEAR and LOOP compared to control. The effect of LINEAR was significant [β (95 %CI): −13.170 (−15.954, −10.386), $p < 0.001$], as well as LOOP [β (95 %CI): −13.849 (−16.633, −11.065), $p < 0.001$]. LINEAR and LOOP differed significantly post-intervention ($p < 0.001$). The LOOP [Emmeans = 29.8 (28.4–31.2)] had a better effect on reducing rumination compared to the LINEAR [Emmeans = 34.7 (33.3–36.1)].

For SQ, group * time estimated mean change differences between LINEAR and LOOP compared to control. The effect of LINEAR and LOOP psychotherapy was significant [LINEAR: β (95 %CI): −3.730 (−4.523, −2.936), $p < 0.001$; LOOP: −4.340 (−5.133, −3.546), $p < 0.001$]. LINEAR and LOOP differed significantly post-intervention ($p < 0.001$). The LOOP [Emmeans = 4.69 (4.23–5.14)] had a better effect on enhancing SQ compared to the LINEAR [Emmeans = 5.84 (5.39–6.29)].

Mediation analysis of ACT's efficacy

The mediating effect was significant when intervention membership (LINEAR verses control) was the predictor, PF changes were the mediator, and SQ changes were the outcome, with a mediating effect of 0.618 (SE = 0.131; 95 % CI: 0.375, 0.886), accounting for 45 % of the total effect of 1.377. For rumination changes as the outcome, the mediating effect was 1.833 (SE = 0.618; 95 % CI: 0.616, 3.026), accounting for 33 % of the total effect of 5.598. When intervention membership (LOOP verses control) was the predictor, PF changes were the mediator, and SQ changes were the outcome, with a mediating effect of 1.086 (SE = 0.271; 95 % CI: 0.528, 1.612), accounting for 43 % of the total effect of 2.497. For rumination changes as the outcome, the mediating effect was 4.123 (SE = 1.197; 95 % CI: 1.762, 6.431), accounting for 41 % of the total effect of 9.962. Further analysis compared the superiority of LOOP to LINEAR interventions, with intervention membership (LINEAR verses LOOP) as the predictor, PF changes as the mediator, and SQ changes were the outcome, with a mediating effect of 0.421 (SE = 0.119; 95 % CI: 0.203, 0.669), accounting for 38 % of the total effect of 1.12. For rumination changes as the outcome, the mediating effect was 1.352 (SE = 0.535; 95 % CI: 0.340, 2.443), accounting for 31 % of the total effect of 4.365 (see Supplementary Table S5).

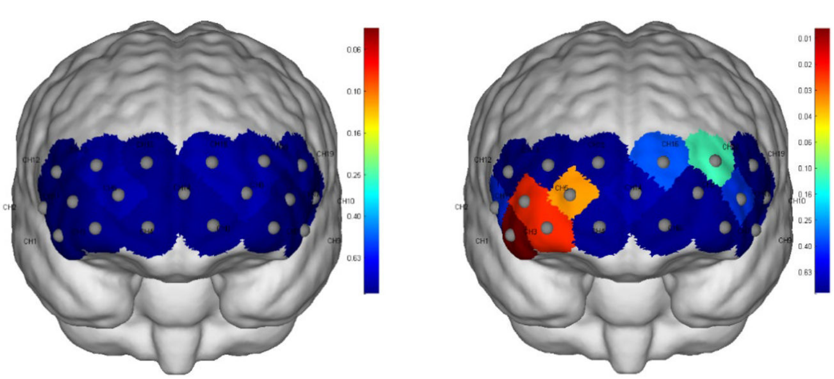
iACT interventions on cortical activation

Of the 477 participants, 210 agreed to baseline brain imaging, and 152 completed follow-up imaging post-intervention. Two participants were excluded due to poor-quality baseline fNIRS data, leaving 150 participants for analysis. The three fNIRS groups showed no significant differences in demographics, outcome variables, or cortical activation across the 19 channels prior to the intervention (see Supplementary Table S6 and Fig. 3). They also did not differ significantly from the trial's baseline sample (Supplementary Table S7).

As shown in Figs. 4, 3B and supplementary Table S8, statistically significant differences of oxyHb activations in Channel 1 (mainly located in the DLPFC) were observed in both LINEAR and LOOP post-intervention [LINEAR: β (95 %CI): 0.053 (0.021, 0.085), FDR-adjusted $p = 0.007$; LOOP: β (95 %CI): 0.051 (0.024, 0.079), FDR-adjusted $p = 0.007$]. Additionally, significant oxyHb activation differences were observed in LOOP at Channel 5 (mainly located in the frontopolar area) [β (95 %CI): 0.052 (0.019, 0.083), FDR-adjusted $p = 0.002$]. However, no significant changes were identified in control group.

iACT interventions on VFT-related brain connectivity

After functional connectivity calculation, two 19 × 19 correlation matrices were generated (supplementary Fig. S3). Supplementary



(A) (B)

Fig. 3. (A) p-values for group differences in cortical activation across each channel of in pre-intervention. (B) the p-values in post-intervention.

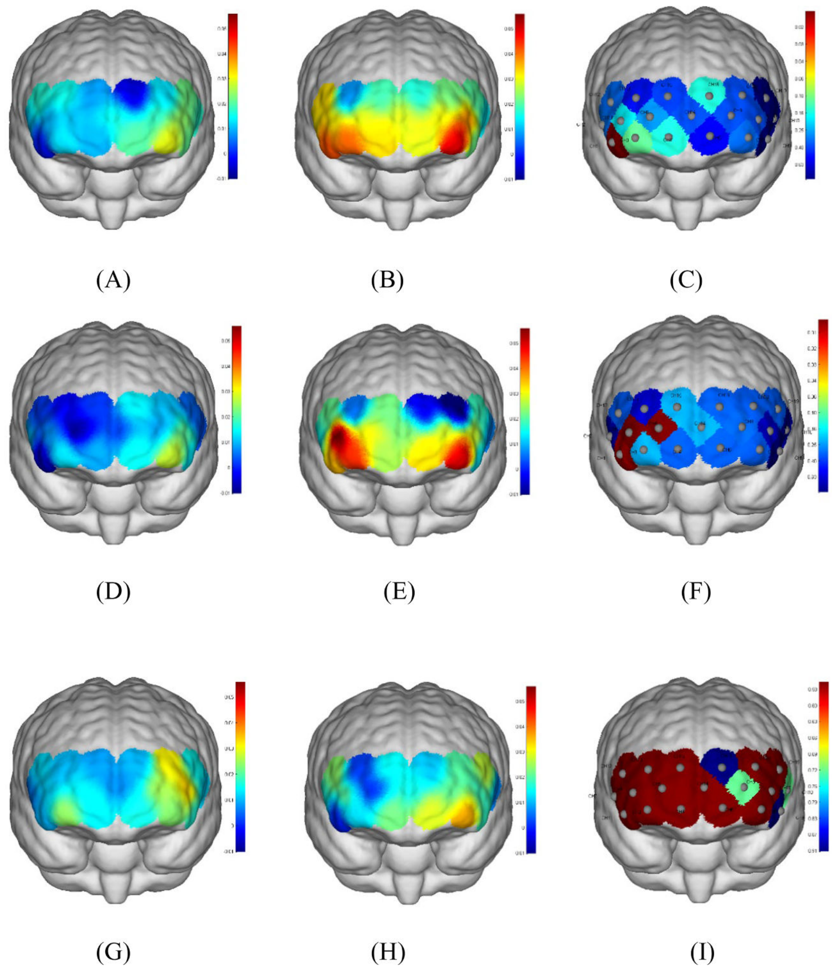


Fig. 4. (A) Mean Oxy-Hb changes of linear group in pre-intervention. (B) Mean Oxy-Hb changes of linear group in post-intervention. (C) *p*-values of each channel for pre- and post- comparison in linear group. (D) Mean Oxy-Hb changes of loop group in pre-intervention. (E) Mean Oxy-Hb changes of loop group in post-intervention. (F) *p*-values of each channel for pre- and post-comparison in loop group. (G) Mean Oxy-Hb changes of control group in pre-intervention. (H) Mean Oxy-Hb changes of control group in post-intervention. (I) *p*-values of each channel for pre- and post-comparison in control group.

Table S8 shows no significant channel-to-channel connectivity changes in either the LINEAR or LOOP groups post-intervention [LINEAR: β (95 %CI): −0.032 (−0.129, 0.647), FDR-adjusted $p = 0.621$; LOOP: β (95 % CI): −0.067 (−0.164, 0.030), FDR-adjusted $p = 0.268$].

Mediation analysis of neural mechanism in act efficacy

The mediating effect was significant when intervention membership (LINEAR verses control) was the predictor, Channel 1 changes were the mediator, and SQ changes were the outcome, with a mediating effect of 1.144 (SE = 0.290; 95 % CI: 0.609, 1.743), accounting for 33 % of the total effect of 3.48. For PF changes as the outcome, the mediating effect was 4.918 (SE = 1.564; 95 % CI: 2.037, 8.137), accounting for 27 % of the total effect of 18.14. For rumination changes as the outcome, the mediating effect was 2.427 (SE = 1.004; 95 % CI: 0.517, 4.415), accounting for 26 % of the total effect of 9.2. Similarly, when intervention membership (LOOP verses control) was the predictor, Channel 1 changes were the mediator, and SQ changes were the outcome, the mediating effect was 1.361 (SE = 0.345; 95 % CI: 0.718, 2.101), accounting for 70 % of the total effect of 1.94. For PF changes as the outcome, the mediating effect was 9.371 (SE = 1.450; 95 % CI: 6.680, 12.369), accounting for 31 % of the total effect of 29.78. For rumination changes as the outcome, the mediating effect was 7.886 (SE = 1.085; 95 % CI: 5.782, 10.064), accounting for 50 % of the total effect of 15.84 (see Supplementary Table S9).

Further exploration of the superior effect of LOOP with Channel 5 changes as the mediator showed a mediating effect of 0.876 (SE = 0.329; 95 % CI: 0.286, 1.580), accounting for 26 % of the total effect of 3.36, partially mediating the relationship between intervention and SQ changes (see Supplementary Table S10). This effect was not observed for rumination or PF.

Discussion

The study explored the efficacy of self-developed iACT loop (LOOP) and linear (LINEAR) psychotherapy models for nurses with poor sleep quality compared to a wait-list control. Both models significantly improved PF, SQ, and reduced rumination, with the culturally adapted LOOP model showing greater efficacy through enhanced psychological flexibility. Both models enhanced activation in the DLPFC, LOOP also stimulated the frontopolar area. Changes in the DLPFC mediated the relationship between intervention and outcome improvements, highlighting its role in ACT's neural mechanism. Frontopolar changes mediated only SQ improvements, not rumination or PF, suggesting the need for further research on LOOP's neural mechanism of superior effects. Moreover, there were no significant changes in functional connectivity during VFT following the intervention, indicating an unclear link between ACT and task-state functional connectivity.

The study demonstrated that both models enhanced PF, with LOOP showing superior efficacy, likely due to its cultural adaptation.

Systematic reviews and meta-analyses have shown that culturally adapted treatments are more effective, acceptable, and satisfying for patients (Chowdhary et al., 2014; Hall et al., 2016; Soto et al., 2018). Participants find culturally adapted ACT enjoyable and acceptable (Chowdhary et al., 2014; Perry et al., 2019; 2024). The LOOP, follows the four step of "启-承-转-合 (Starting-Proceeding-Transforming-Integrating)" to deliver contents, aligns well with Chinese cultural context, making it more easily accepted by participants (Ding et al., 2020) and helping them manage distress and feel more comfortable seeking social support (Xu et al., 2020). Our findings suggest that this model could be applicable to other Chinese cohorts.

Both models improved sleep quality, with LOOP proving more effective through enhanced psychological flexibility. Its unique design introduced all six facets in the first session, with subsequent sessions reinforcing core ACT concepts. This approach encouraged participants to focus on their most inflexible facet early on, potentially increasing psychological flexibility from the outset and supporting a comprehensive therapeutic journey (Janeslätt et al., 2019; Mendoza et al., 2020). Given the close association between psychological flexibility and sleep, enhancing overall psychological flexibility contributes to improved sleep quality (Kato, 2016). LOOP potentially empowers participants to actively accept sleep difficulties from the first session, reshaping their beliefs and attitudes, which is a well-established treatment strategy (Chapoutot et al., 2021).

Both models reduced rumination, with LOOP outperforming LINEAR by enhancing psychological flexibility. This advantage likely stems from its repetitive presentation of intervention materials, which allows participants to master core ACT content through six repetitions, potentially making it more effective in increasing psychological flexibility. This repetitive intervention mode has been effectively applied in various psychological domains. For instance, exposure therapy involves repeatedly exposing patients to anxiety-provoking stimuli to reduce sensitivity (McLean et al., 2022; van Loenen et al., 2022). Similarly, CBT employs repeated cognitive restructuring and behavioral exercises to alter maladaptive cognitive patterns and behaviors (Cuijpers et al., 2020; Pardos-Gascón et al., 2021). In educational psychology, repeated reading enhances reading fluency and comprehension by having students read the same text multiple times (Alqahtani, 2020; O'Connor et al., 2007). Additionally, repetitive practice strengthens neural pathways, facilitating skill automation and proficiency (Dayan & Cohen, 2011; Macnamara et al., 2016). Our research applied this repetitive mode in LOOP, demonstrating promising results, suggesting its potential replication in future ACT interventions to enhance efficacy.

This study is the first to investigate the neural mechanism of ACT on nurses with poor sleep quality. Our findings indicated increased activation in the DLPFC post-ACT intervention, suggesting enhanced cognitive resource recruitment during VFT following ACT. The significant mediating effects imply that ACT interventions may enhance cognitive resources and emotional regulation through DLPFC activation, leading to improvements in sleep quality and psychological flexibility, and reductions in rumination. These neural changes align with previous research highlighting the role of the DLPFC in cognitive control and emotion regulation (Lévesque et al., 2003; Shackman et al., 2009). Additionally, prior research has shown a weakened right prefrontal lobe network in the development of chronic insomnia disorder (Gong et al., 2022), with the DLPFC being a target in sleep intervention studies (Gong et al., 2020). fMRI studies have consistently demonstrated increased activity in the prefrontal cortex, including the DLPFC, and decreased subcortical activity resembling the Defusion facet of ACT (Creswell et al., 2007; Koenigsberg et al., 2010; Lee et al., 2023; Wang et al., 2022). Overall, our results suggest that the DLPFC could be a potential neural mechanism of ACT. Future research should continue to validate these findings and further explore how this neural pathway can be leveraged to optimize the efficacy of ACT.

Our study also reveals that the LOOP stimulates frontopolar activation, aligning with previous research linking reduced local computational deep sleep in the frontopolar area with obstructive sleep apnea (Jussila et al., 2016) and its association with slow-wave sleep (Ferrara et al., 2002). However, our mediation analysis indicates that changes in the frontopolar area only partially mediate the relationship between the intervention and SQ improvements, but not rumination or PF. This suggests that while frontopolar activation contributes to the enhanced sleep quality observed with the LOOP intervention, it does not significantly impact rumination or PF. These findings highlight the specificity of mechanisms underlying LOOP's superior effect and underscore the need for further research to clarify them.

Lastly, our study found no significant changes in task-related functional connectivity. Prior evidence on ACT's impact in this context is limited. For instance, in patients with obsessive-compulsive disorder, post-ACT fMRI revealed strengthened connectivity in certain brain regions (Lee et al., 2023), suggesting an unclear link between ACT and task-related functional connectivity. Our study is the first to report VFT-related brain connectivity following ACT in individuals with poor sleep, contributing to the growing body of evidence on ACT's impact on task-independent connectivity.

The study has several notable limitations. Firstly, the nurses were exclusively from one Hospital, suggesting the need for future research involving nurses from diverse geographic areas to enhance the generalizability of findings. Secondly, this study solely analyzed pre- and post-intervention data, without incorporating follow-up measurements. Future research should include follow-up assessments to further investigate the efficacy of iACT. Lastly, the cultural adaptation of the LOOP model was based on traditional Chinese culture, potentially limiting its generalizability to populations outside of China. Future research should explore its applicability in other cultural contexts to validate its effectiveness.

Conclusion

Both models significantly improved sleep quality, psychological flexibility, and reduced rumination through enhanced psychological flexibility, with LOOP exhibiting superior efficacy. While both models increased activation in the prefrontal cortex, LOOP additionally stimulated the frontopolar area. Mediation analyses underscore the role of DLPFC activation in understanding ACT's neural mechanisms for insomnia treatment, highlighting the need for further research into the mechanisms of LOOP's superior effect.

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Data statement

The raw data of the present study are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Difan Wang: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. **Bingyan Lin:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. **Jiaxue Du:** Formal analysis, Writing – review & editing. **Wenyu Liu:** Formal analysis, Writing – review & editing. **Tong Sun:** Data curation. **Qingyi Li:** Data curation. **Lijun Xiao:** Funding acquisition, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijchp.2025.100543.

References

Alqahtani, S. S. (2020). iPad and repeated reading to improve reading comprehension for young adults with intellectual disability. *Research in Developmental Disabilities, 103*, Article 103703. https://doi.org/10.1016/j.ridd.2020.103703

Altena, E., Van Der Werf, Y. D., Sanz-Arigita, E. J., Voorn, T. A., Rombouts, S. A., Kuijer, J. P., & Van Someren, E. J. (2008). Prefrontal hypoactivation and recovery in insomnia. *Sleep, 31*(9), 1271–1276.

Althobaity, A., & Alshammari, F. (2020). Nurses on the Frontline against the COVID-19 Pandemic: An integrative review. *Dubai Medical Journal*, 3.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders: DSM-5™ (5th ed.). *CoDAS, 25*(2), 191.

Aytur, S. A., Ray, K. L., Meier, S. K., Campbell, J., Gendron, B., Waller, N., & Robin, D. A. (2021). Neural mechanisms of acceptance and commitment therapy for chronic pain: A network-based fMRI approach. *Frontiers in Human Neuroscience, 15*, Article 587018. https://doi.org/10.3389/fnhum.2021.587018

Ballesio, A., Bacaro, V., Vacca, M., Chirico, A., Lucidi, F., Riemann, D., … Lombardo, C. (2021). Does cognitive behaviour therapy for insomnia reduce repetitive negative thinking and sleep-related worry beliefs? A systematic review and meta-analysis. *Sleep Medicine Reviews, 55*, Article 101378. https://doi.org/10.1016/j.smrv.2020.101378

Barnes, L. L., Dhana, K., Liu, X., Carey, V. J., Ventrelle, J., Johnson, K., … Sacks, F. M. (2023). Trial of the MIND Diet for Prevention of Cognitive Decline in Older Persons. *The New England Journal Of Medicine, 389*(7), 602–611. https://doi.org/10.1056/NEJMoa2302368

Bernal, G., Jiménez-Chafey, M. I., & Rodríguez, M. M. D. (2009). Cultural adaptation of treatments: A resource for considering culture in evidence-based practice. *Professional Psychology-Research and Practice, 40*(4), 361–368. https://doi.org/10.1037/a0016401

Bouchard, S., Bastien, C., & Morin, C. M. (2003). Self-efficacy and adherence to cognitive-behavioral treatment of insomnia. *Behavioral Sleep Medicine, 1*(4), 187–199. https://doi.org/10.1207/s15402010bsm0104_2

Broomfield, N. M., & Espie, C. A. (2005). Towards a valid, reliable measure of sleep effort. *Journal of Sleep Research, 14*(4), 401–407. https://doi.org/10.1111/j.1365-2869.2005.00481.x

Brosschot, J. F., Gerin, W., & Thayer, J. F. (2006). The perseverative cognition hypothesis: a review of worry, prolonged stress-related physiological activation, and health. *Journal of Psychosomatic Research, 60*(2), 113–124. https://doi.org/10.1016/j.jpsychores.2005.06.074

Brunet, J., Tulloch, H. E., Wolfe Phillips, E., Reid, R. D., Pipe, A. L., & Reed, J. L. (2020). Motivation predicts change in nurses' physical activity levels during a web-based worksite intervention: results from a randomized trial. *Journal of Medical Internet Research, 22*(9), e11543. https://doi.org/10.2196/11543

Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The pittsburgh sleep quality index: a new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Chapoutot, M., Peter-Derex, L., Bastuji, H., Leslie, W., Schoendorff, B., Heinzer, R., … Putois, B. (2021). Cognitive behavioral therapy and acceptance and commitment therapy for the discontinuation of long-term benzodiazepine use in insomnia and anxiety disorders. *International Journal Of Environmental Research And Public Health, 18*(19). https://doi.org/10.3390/ijerph181910222

Chowdhary, N., Jotheeswaran, A. T., Nadkarni, A., Hollon, S. D., King, M., Jordans, M. J., … Patel, V. (2014). The methods and outcomes of cultural adaptations of psychological treatments for depressive disorders: a systematic review. *Psychological Medicine, 44*(6), 1131–1146. https://doi.org/10.1017/s0033291713001785

Creswell, J. D., Way, B. M., Eisenberger, N. I., & Lieberman, M. D. (2007). Neural correlates of dispositional mindfulness during affect labeling. *Psychosomatic medicine, 69*(6), 560–565. https://doi.org/10.1097/PSY.0b013e3180f6171f

Csipo, T., Lipecz, A., Owens, C., Mukli, P., Perry, J. W., Tarantini, S., … Yabluchanskiy, A. (2021). Sleep deprivation impairs cognitive performance, alters task-associated cerebral blood flow and decreases cortical neurovascular coupling-related hemodynamic responses. *Scientific Reports, 11*(1), 20994. https://doi.org/10.1038/s41598-021-00188-8

Cuijpers, P., Karyotaki, E., de Wit, L., & Ebert, D. D. (2020). The effects of fifteen evidence-supported therapies for adult depression: A meta-analytic review. *Psychotherapy Research : Journal of the Society for Psychotherapy Research, 30*(3), 279–293. https://doi.org/10.1080/10503307.2019.1649732

Dalrymple, K. L., Fiorentino, L., Politi, M. C., & Posner, D. (2010). Incorporating principles from acceptance and commitment therapy into cognitive-behavioral therapy for Insomnia: A case example. *Journal of Contemporary Psychotherapy, 40*(4), 209–217. https://doi.org/10.1007/s10879-010-9145-1

Daly-Eichenhardt, A., Scott, W., Howard-Jones, M., Nicolaou, T., & McCracken, L. M. (2016). Changes in sleep problems and psychological flexibility following interdisciplinary acceptance and commitment therapy for chronic pain: An observational cohort study. *Frontiers in Psychology, 7*, 1326. https://doi.org/10.3389/fpsyg.2016.01326

Dayan, E., & Cohen, L. G. (2011). Neuroplasticity subserving motor skill learning. *Neuron, 72*(3), 443–454. https://doi.org/10.1016/j.neuron.2011.10.008

Ding, Y., Wang, L., Chen, J., Zhao, J., & Guo, W. (2020). Chinese taoist cognitive therapy for symptoms of depression and anxiety in adults in China: A systematic review and meta-analysis. *Frontiers in psychology, 11*, 769. https://doi.org/10.3389/fpsyg.2020.00769

Duarte, J., & Pinto-Gouveia, J. (2017). The role of psychological factors in oncology nurses' burnout and compassion fatigue symptoms. *European Journal Of Oncology Nursing, 28*, 114–121. https://doi.org/10.1016/j.ejon.2017.04.002

Feng, H. L., Qi, X. X., Xia, C. L., Xiao, S. Q., & Fan, L. (2021). Association between night shift and sleep quality and health among Chinese nurses: A cross-sectional study. *Journal of nursing management, 29*(7), 2123–2131. https://doi.org/10.1111/jonm.13351

Ferrara, M., De Gennaro, L., Curcio, G., Cristiani, R., Corvasce, C., & Bertini, M. (2002). Regional differences of the human sleep electroencephalogram in response to selective slow-wave sleep deprivation. *Cerebral cortex (New York, N.Y. : 1991), 12*(7), 737–748. https://doi.org/10.1093/cercor/12.7.737

Firew, T., Sano, E. D., Lee, J. W., Flores, S., Lang, K., Salman, K., … Chang, B. P. (2020). Protecting the front line: a cross-sectional survey analysis of the occupational factors contributing to healthcare workers' infection and psychological distress during the COVID-19 pandemic in the USA. *BMJ open, 10*(10), Article e042752. https://doi.org/10.1136/bmjopen-2020-042752

Frøjd, L. A., Papageorgiou, C., Munkhaugen, J., Moum, T., Sverre, E., Nordhus, I. H., & Dammen, T. (2022). Worry and rumination predict insomnia in patients with coronary heart disease: a cross-sectional study with long-term follow-up. *Journal of Clinical Sleep Medicine : JCSM, 18*(3), 779–787. https://doi.org/10.5664/jcsm.9712

Geiger-Brown, J. M., Rogers, V. E., Liu, W., Ludeman, E. M., Downton, K. D., & Diaz-Abad, M. (2015). Cognitive behavioral therapy in persons with comorbid insomnia: A meta-analysis. *Sleep medicine Reviews, 23*, 54–67. https://doi.org/10.1016/j.smrv.2014.11.007

Gong, H., Sun, H., Ma, Y., Tan, Y., Cui, M., Luo, M., & Chen, Y. (2022). Prefrontal brain function in patients with chronic insomnia disorder: A pilot functional near-infrared spectroscopy study. *Frontiers in Neurology, 13*, Article 985988. https://doi.org/10.3389/fneur.2022.985988

Gong, L., Xu, R. H., Qin, M. H., Liu, D., Zhang, B., Bi, Y. C., & Xi, C. H. (2020). New potential stimulation targets for noninvasive brain stimulation treatment of chronic insomnia. *Sleep Medicine, 75*, 380–387. https://doi.org/10.1016/j.sleep.2020.08.021

Guastella, A. J., & Moulds, M. L. (2007). The impact of rumination on sleep quality following a stressful life event. *Personality & Individual Differences, 42*(6), 1151–1162.

Hall, G. C., Ibaraki, A. Y., Huang, E. R., Marti, C. N., & Stice, E. (2016). A meta-analysis of cultural adaptations of psychological interventions. *Behavior Therapy, 47*(6), 993–1014. https://doi.org/10.1016/j.beth.2016.09.005

Han, X., & Yang, H. (2009). Chinese version of nolen-hoeksema ruminative responses scale (RRS) used in 912 college students: Reliability and validity. *Chinese Journal of Clinical Psychology, 17*(05). https://doi.org/10.16128/j.cnki.1005-3611.2009.05.028, 550-551+549.

Han, Y., Yuan, Y., Zhang, L., & Fu, Y. (2016). Sleep disorder status of nurses in general hospitals and its influencing factors. *Psychiatria Danubina, 28*(2), 176–183.

Harvey, A. G. (2002). A cognitive model of insomnia. *Behaviour Research And Therapy, 40*(8), 869–893. https://doi.org/10.1016/s0005-7967(01)00061-4

Harvey, A. G., Tang, N. K., & Browning, L. (2005). Cognitive approaches to insomnia. *Clinical psychology Review, 25*(5), 593–611. https://doi.org/10.1016/j.cpr.2005.04.005

Hayes, A. F., & Preacher, K. J. (2014). Statistical mediation analysis with a multicategorical independent variable. *The British Journal Of Mathematical And Statistical Psychology, 67*(3), 451–470. https://doi.org/10.1111/bmsp.12028

Hayes, S. C., Luoma, J. B., Bond, F. W., Masuda, A., & Lillis, J. (2006). Acceptance and commitment therapy: model, processes and outcomes. *Behaviour Research and Therapy, 44*(1), 1–25. https://doi.org/10.1016/j.brat.2005.06.006

Hayes, S. C., Strosahl, K. D., & Wilson, K. G. (2012). *Acceptance and commitment therapy: The process and practice of mindful change* (2nd ed.). New York: Guilford Press.

Hedman, E., Andersson, E., Lindefors, N., Andersson, G., Rück, C., & Ljótsson, B. (2013). Cost-effectiveness and long-term effectiveness of internet-based cognitive behaviour therapy for severe health anxiety. *Psychological Medicine, 43*(2), 363–374. https://doi.org/10.1017/s0033291712001079

Herold, F., Wiegel, P., Scholkmann, F., & Müller, N. G. (2018). Applications of functional near-infrared spectroscopy (fNIRS) neuroimaging in exercise‑cognition science: A systematic, methodology-focused review. *Journal of Clinical Medicine, 7*(12). https://doi.org/10.3390/jcm7120466

Jäger, M., Terry, J., & Rance, J. (2021). A Mindful ACT'- testing the feasibility and acceptability of a brief psychosocial intervention designed to accompany osteopathy treatment for people who live with persistent pain. *International Journal of Osteopathic Medicine, 42*, 85–91. https://doi.org/10.1016/j.ijosm.2021.12.004

Janeslätt, G., Ahlström, S. W., & Granlund, M. (2019). Intervention in time-processing ability, daily time management and autonomy in children with intellectual disabilities aged 10-17 years - A cluster randomised trial. *Australian Occupational Therapy Journal, 66*(1), 110–120. https://doi.org/10.1111/1440-1630.12547

Jensen, K. B., Kosek, E., Wicksell, R., Kemani, M., Olsson, G., Merle, J. V., … Ingvar, M. (2012). Cognitive behavioral therapy increases pain-evoked activation of the prefrontal cortex in patients with fibromyalgia. *Pain, 153*(7), 1495–1503. https://doi.org/10.1016/j.pain.2012.04.010

Jussila, M., Saarenpää-Heikkilä, O., Huupponen, E., Lapinlampi, A. M., Penttala, J., & Himanen, S. L. (2016). Sleep apnea reduces the amount of computational deep sleep in the right frontopolar area in school-aged children. *Clinical Neurophysiology, 127*(5), 2167–2174. https://doi.org/10.1016/j.clinph.2016.02.016

Kato, T. (2016). Impact of psychological inflexibility on depressive symptoms and sleep difficulty in a Japanese sample. *SpringerPlus, 5*(1), 712. https://doi.org/10.1186/s40064-016-2393-0

Kocovski, N. L., Fleming, J. E., & Rector, N. A. (2009). Mindfulness and Acceptance-Based Group Therapy for Social Anxiety Disorder: An Open Trial. *Cognitive and Behavioral Practice, 16*(3), 276–289. https://doi.org/10.1016/j.cbpra.2008.12.004

Koenigsberg, H. W., Fan, J., Ochsner, K. N., Liu, X., Guise, K., Pizzarello, S., … Siever, L. J. (2010). Neural correlates of using distancing to regulate emotional responses to social situations. *Neuropsychologia, 48*(6), 1813–1822. https://doi.org/10.1016/j.neuropsychologia.2010.03.002

Kurebayashi, Y. (2020). Effects of self-compassion and self-focus on sleep disturbances among psychiatric nurses. *Perspectives in Psychiatric Care, 56*(2), 474–480. https://doi.org/10.1111/ppc.12458

Lee, S. W., Kim, S., Lee, S., Seo, H. S., Cha, H., Chang, Y., & Lee, S. J. (2023). Neural mechanisms of acceptance-commitment therapy for obsessive-compulsive disorder: a resting-state and task-based fMRI study. *Psychological Medicine*, 1–11. https://doi.org/10.1017/s0033291723001769

Leerssen, J., Blanken, T. F., Pozzi, E., Jahanshad, N., Aftanas, L., Andreassen, O. A., … Van Someren, E. J. W. (2020). Brain structural correlates of insomnia severity in 1053 individuals with major depressive disorder: results from the ENIGMA MDD Working Group. *Translational Psychiatry, 10*(1), 425. https://doi.org/10.1038/s41398-020-01109-5

Lenth, R. V. (2024). *emmeans: Estimated marginal means, aka least-squares means. R package version 1.7.0.* https://CRAN.R-project.org/package=emmeans.

Lévesque, J., Eugène, F., Joanette, Y., Paquette, V., Mensour, B., Beaudoin, G., … Beauregard, M. (2003). Neural circuitry underlying voluntary suppression of sadness. *Biological psychiatry, 53*(6), 502–510. https://doi.org/10.1016/s0006-3223(02)01817-6

Lin, Y.-Y., Rogge, R. D., & Swanson, D. P. (2020). Cross-cultural flexibility: Validation of the traditional Mandarin, simplified Mandarin, and Japanese translations of the Multidimensional Psychological Flexibility Inventory. *Journal of Contextual Behavioral Science, 15*, 73–84. https://doi.org/10.1016/j.jcbs.2019.11.008

Liu, J., Zhu, L., & Su, Y. (2020). Comparative effectiveness of high-intensity interval training and moderate-intensity continuous training for cardiometabolic risk factors and cardiorespiratory fitness in childhood obesity: A meta-analysis of randomized controlled trials. *Frontiers in Physiology, 11*, 214. https://doi.org/10.3389/fphys.2020.00214

Liu, X., Tnag, M., Hu, L., & Wang, A. (1996). Reliability and validity of the Pittsburgh sleep quality index. *Chinese Journal of Psychiatry, 29*(2), 5.

Macnamara, B. N., Moreau, D., & Hambrick, D. Z. (2016). The relationship between deliberate practice and performance in sports: A meta-analysis. *Perspectives on Psychological Science : a Journal of the Association for Psychological Science, 11*(3), 333–350. https://doi.org/10.1177/1745691616635591

Martin, J. L., Carlson, G. C., Kelly, M. R., Song, Y., Mitchell, M. N., Josephson, K. R., … Yano, E. M. (2023). Novel treatment based on acceptance and commitment therapy versus cognitive behavioral therapy for insomnia: A randomized comparative effectiveness trial in women veterans. *Journal of Consulting And Clinical Psychology, 91*(11), 626–639. https://doi.org/10.1037/ccp0000836

Massimini, M., Huber, R., Ferrarelli, F., Hill, S., & Tononi, G. (2004). The sleep slow oscillation as a traveling wave. *The Journal of Neuroscience, 24*(31), 6862–6870. https://doi.org/10.1523/jneurosci.1318-04.2004

McLean, C. P., Levy, H. C., Miller, M. L., & Tolin, D. F. (2022). Exposure therapy for PTSD: A meta-analysis. *Clinical psychology review, 91*, Article 102115. https://doi.org/10.1016/j.cpr.2021.102115

Mendoza, M. D. C., Jiménez, A., Sánchez-Queija, I., & Freijo, E. (2020). Emotional autonomy and adjustment among emerging adults: The moderating role of family relationships: Emotional autonomy and adjustment among emerging adults. *Scandinavian Journal of Psychology, 61*. https://doi.org/10.1111/sjop.12614

Mieda, M., & Sakurai, T. (2013). Orexin (Hypocretin) receptor agonists and antagonists for treatment of sleep disorders. *CNS Drugs, 27*(2).

Morin, C. M. (1993). *Insomnia: Psychological Assessment and Management*. New York; London: Guilford Press.

Nagayama Hall, G. C., Hong, J. J., Zane, N. W., & Meyer, O. L (2011). Culturally-competent treatments for Asian Americans: The relevance of mindfulness and acceptance-based psychotherapies. *Clinical psychology : a Publication of the Division of Clinical Psychology of the American Psychological Association, 18*(3), 215–231. https://doi.org/10.1111/j.1468-2850.2011.01253.x

Newby, J., Mason, E., Kladnistki, N., Murphy, M., Millard, M., Haskelberg, H., … Mahoney, A. (2021). Integrating internet CBT into clinical practice: a practical guide for clinicians. *Clinical Psychologist, 25*(2), 164–178. https://doi.org/10.1080/13284207.2020.1843968

Nolen-Hoeksema, S. (1991). Responses to depression and their effects on the duration of depressive episodes. *Journal of Abnormal Psychology, 100*(4), 569–582. https://doi.org/10.1037//0021-843x.100.4.569

Nolen-Hoeksema, S., & Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: the 1989 Loma Prieta Earthquake. *Journal of Personality And Social Psychology, 61*(1), 115–121. https://doi.org/10.1037//0022-3514.61.1.115

O'Connor, R. E., White, A., & Swanson, H. L. (2007). Repeated reading versus continuous reading: influences on reading fluency and comprehension. *Exceptional Children, 74*(1), 31–46. https://doi.org/10.1177/001440290707400102

Ong, J. C., & Smith, C. E. (2017). Using mindfulness for the treatment of Insomnia. *Current sleep medicine reports, 3*(2), 57–65. https://doi.org/10.1007/s40675-017-0068-1

Paivi, L., Sitwat, L., Harri, O. K., Joona, M., & Raimo, L. (2019). ACT for sleep - Internet-delivered self-help ACT for sub-clinical and clinical insomnia: A randomized controlled trial. *Journal of Contextual Behavioral Science, 12*, 119–127. https://doi.org/10.1016/j.jcbs.2019.04.001

Pardos-Gascón, E. M., Narambuena, L., Leal-Costa, C., & van-der Hofstadt-Román, C. J. (2021). Differential efficacy between cognitive-behavioral therapy and mindfulness-based therapies for chronic pain: Systematic review. *International Journal Of Clinical And Health Psychology : IJCHP, 21*(1), Article 100197. https://doi.org/10.1016/j.ijchp.2020.08.001

Patel, D., Steinberg, J., & Patel, P. (2018). Insomnia in the Elderly: A Review. *Journal of Clinical Sleep Medicine : JCSM, 14*(6), 1017–1024. https://doi.org/10.5664/jcsm.7172

Perry, A., Gardener, C., Oliver, J. E., Ta, I., & Zen, C. (2019). Exploring the cultural flexibility of the ACT model as an effective therapeutic group intervention for Turkish speaking communities in East London. In *The Cognitive Behaviour Therapist, 12*. https://doi.org/10.1017/S1754470X18000041

Perry, A., Gardener, C., Shieh, J., Hồ, Q. T., Doan, A., & Bhui, K. (2024). Investigating the acceptability of a culturally adapted acceptance and commitment therapy group for UK Vietnamese communities: A practice-based feasibility study. *Transcult Psychiatry*. https://doi.org/10.1177/13634615241228071, 13634615241228071.

Peter, L., Reindl, R., Zauter, S., Hillemacher, T., & Richter, K. (2019). Effectiveness of an Online CBT-I Intervention and a Face-to-Face Treatment for Shift Work Sleep Disorder: A Comparison of Sleep Diary Data. *International Journal Of Environmental Research And Public Health, 16*(17). https://doi.org/10.3390/ijerph16173081

Philip, J., & Cherian, V. (2022). Acceptance and commitment therapy in obsessive-compulsive disorder: A case study. *Indian Journal Of Psychological Medicine, 44*(1), 78–82. https://doi.org/10.1177/0253717621996734

Pillai, V., Steenburg, L. A., Ciesla, J. A., Roth, T., & Drake, C. L. (2014). A seven day actigraphy-based study of rumination and sleep disturbance among young adults with depressive symptoms. *Journal of psychosomatic research, 77*(1), 70–75. https://doi.org/10.1016/j.jpsychores.2014.05.004

Pinti, P., Tachtsidis, I., Hamilton, A., Hirsch, J., Aichelburg, C., Gilbert, S., & Burgess, P. W. (2020). The present and future use of functional near-infrared spectroscopy (fNIRS) for cognitive neuroscience. *Annals of the New York Academy of Sciences, 1464*(1), 5–29. https://doi.org/10.1111/nyas.13948

Plichta, M. M., Herrmann, M. J., Baehne, C. G., Ehlis, A. C., Richter, M. M., Pauli, P., & Fallgatter, A. J. (2006). Event-related functional near-infrared spectroscopy (fNIRS): are the measurements reliable? *NeuroImage, 31*(1), 116–124. https://doi.org/10.1016/j.neuroimage.2005.12.008

Reyes, A. T., Bhatta, T. R., Muthukumar, V., & Gangozo, W. J. (2020). Testing the acceptability and initial efficacy of a smartphone-app mindfulness intervention for college student veterans with PTSD. *Archives of Psychiatric Nursing, 34*(2), 58–66. https://doi.org/10.1016/j.apnu.2020.02.004

Rolffs, J. L., Rogge, R. D., & Wilson, K. G. (2018). Disentangling components of flexibility via the Hexaflex Model: Development and validation of the multidimensional psychological flexibility inventory (MPFI). *Assessment, 25*(4), 458–482. https://doi.org/10.1177/1073191116645905

Rosado, I. V., Russo, G. H., & Maia, E. M. (2015). Generating health elicits illness? The contradictions of work performed in emergency care units of public hospitals. *Ciencia & saude coletiva, 20*(10), 3021–3032. https://doi.org/10.1590/1413-812320152010.13202014

Ruiz, F. J., Florez, C. L., Garcia-Martin, M. B., Monroy-Cifuentes, A., Barreto-Montero, K., Garcia-Beltran, D. M., … Gil-Luciano, B. (2018). A multiple-baseline evaluation of a brief acceptance and commitment therapy protocol focused on repetitive negative thinking for moderate emotional disorders. *Journal of Contextual Behavioral Science, 9*, 1–14. https://doi.org/10.1016/j.jcbs.2018.04.004

Salari, N., Khazaie, H., Hosseinian-Far, A., Khaledi-Paveh, B., Ghasemi, H., Mohammadi, M., & Shohaimi, S. (2020). The effect of acceptance and commitment therapy on insomnia and sleep quality: A systematic review. *BMC neurology, 20*(1), 300. https://doi.org/10.1186/s12883-020-01883-1

Saldaña, K. S., McGowan, S. K., & Martin, J. L. (2023). Acceptance and commitment therapy as an adjunct or alternative treatment to cognitive behavioral therapy for Insomnia. *Sleep Medicine Clinics, 18*(1), 73–83. https://doi.org/10.1016/j.jsmc.2022.09.003

Sanders, L. M. J., Hortobágyi, T., la Bastide-van Gemert, S., van der Zee, E. A., & van Heuvelen, M. J. G (2019). Dose-response relationship between exercise and cognitive function in older adults with and without cognitive impairment: A systematic review and meta-analysis. *PloS one, 14*(1), Article e0210036. https://doi.org/10.1371/journal.pone.0210036

Shackman, A. J., McMenamin, B. W., Maxwell, J. S., Greischar, L. L., & Davidson, R. J. (2009). Right dorsolateral prefrontal cortical activity and behavioral inhibition. *Psychological Science, 20*(12), 1500–1506. https://doi.org/10.1111/j.1467-9280.2009.02476.x

Shahkaram, H., Yaztappeh, J. S., Sadeghi, A., Kianimoghadam, A. S., Soltanabadi, S., Bakhtiari, M., & Arani, A. M. (2024). Comparing the effectiveness of transdiagnostic treatment with acceptance and commitment therapy on emotional disorders, rumination, and life satisfaction in patients with irritable bowel syndrome: a randomized clinical trial. *BMC Gastroenterology, 24*(1), 66. https://doi.org/10.1186/s12876-024-03142-w

Shin, J. W., Kim, S., Shin, Y. J., Park, B., & Park, S. (2023). Comparison of acceptance and commitment therapy (ACT) and cognitive behavior therapy (CBT) for chronic Insomnia: A pilot randomized controlled trial. *Nature and Science Of Sleep, 15*, 523–531. https://doi.org/10.2147/nss.S409981

Soto, A., Smith, T. B., Griner, D., Domenech Rodríguez, M., & Bernal, G. (2018). Cultural adaptations and therapist multicultural competence: Two meta-analytic reviews. *Journal of Clinical Psychology, 74*(11), 1907–1923. https://doi.org/10.1002/jclp.22679

Spielman, A. J., Caruso, L. S., & Glovinsky, P. B. (1987). A behavioral perspective on insomnia treatment. *The Psychiatric clinics of North America, 10*(4), 541–553.

Strangman, G., Culver, J. P., Thompson, J. H., & Boas, D. A. (2002). A quantitative comparison of simultaneous BOLD fMRI and NIRS recordings during functional brain activation. *NeuroImage, 17*(2), 719–731.

Sun, J. J., Liu, X. M., Shen, C. Y., Zhang, X. Q., Sun, G. X., Feng, K., … Liu, P. Z. (2017). Reduced prefrontal activation during verbal fluency task in chronic insomnia disorder: a multichannel near-infrared spectroscopy study. *Neuropsychiatric Disease And Treatment, 13*, 1723–1731. https://doi.org/10.2147/ndt.S136774

van Loenen, I., Scholten, W., Muntingh, A., Smit, J., & Batelaan, N. (2022). The effectiveness of virtual reality exposure-based cognitive behavioral therapy for severe anxiety disorders, obsessive-compulsive disorder, and posttraumatic stress disorder: Meta-analysis. *Journal of Medical Internet Research, 24*(2), e26736. https://doi.org/10.2196/26736

Vendela, Zetterqvist, Rebecca, Grudin, Jenny, Rickardsson, … Linda. (2018). Acceptance-based behavioural treatment for insomnia in chronic pain: A clinical pilot study. *Journal of Contextual Behavioral Science on Sciverse Sciencedirect*.

Voldsbekk, I., Groote, I., Zak, N., Roelfs, D., Geier, O., Due-Tønnessen, P., … Maximov, II. (2021). Sleep and sleep deprivation differentially alter white matter microstructure: A mixed model design utilising advanced diffusion modelling. *NeuroImage, 226*, Article 117540. https://doi.org/10.1016/j.neuroimage.2020.117540

Wang, D., Lin, B., Liang, H., Deng, Y., & Zhang, L. (2023). Mediating role of psychological flexibility in the effect of obsessive-compulsive symptoms on sleep quality among nurses during the COVID-19 pandemic. *Current Psychology*. https://doi.org/10.1007/s12144-023-04546-9

Wang, Y., Vantieghem, I., Dong, D., Nemegeer, J., De Mey, J., Van Schuerbeek, P., … Vandekerckhove, M. (2022). Approaching or decentering? differential neural networks underlying experiential emotion regulation and cognitive defusion. *Brain sciences, 12*(9). https://doi.org/10.3390/brainsci12091215

Wewege, M., van den Berg, R., Ward, R. E., & Keech, A. (2017). The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis. *Obesity reviews : an official journal of the International Association for the Study of Obesity, 18*(6), 635–646. https://doi.org/10.1111/obr.12532

Winzeler, K., Voellmin, A., Schäfer, V., Meyer, A. H., Cajochen, C., Wilhelm, F. H., & Bader, K. (2014). Daily stress, presleep arousal, and sleep in healthy young women: a daily life computerized sleep diary and actigraphy study. *Sleep medicine, 15*(3), 359–366. https://doi.org/10.1016/j.sleep.2013.09.027

Wu, Y., Zhuang, Y., & Qi, J. (2020). Explore structural and functional brain changes in insomnia disorder: A PRISMA-compliant whole brain ALE meta-analysis for multimodal MRI. *Medicine, 99*(14), e19151. https://doi.org/10.1097/md.0000000000019151

Xu, H. Z., O'Brien, W. H., & Chen, Y. W. (2020). Chinese international student stress and coping: A pilot study of acceptance and commitment therapy. *Journal of Contextual Behavioral Science, 15*, 135–141. https://doi.org/10.1016/j.jcbs.2019.12.010

Yan, D. Q., Huang, Y. X., Chen, X., Wang, M., Li, J., & Luo, D. (2021). Application of the Chinese version of the pittsburgh sleep quality index in people living with hiv: preliminary reliability and validity. *Frontiers in psychiatry, 12*, Article 676022. https://doi.org/10.3389/fpsyt.2021.676022

Yang, J., Ling, Y., Xiao, J., & Yao, S. (2009). The Chinese version of ruminative responses scale in high school students: Its reliability and validity. *Chinese Journal of Clinical Psychology, 17*(1), 3. https://doi.org/10.16128/j.cnki.1005-3611.2009.01.021

Ye, J., Mao, A., Wang, J., Okoli, C. T. C., Zhang, Y., Shuai, H., … Zhuang, L. (2020). From twisting to settling down as a nurse in China: a qualitative study of the commitment to nursing as a career. *BMC Nursing, 19*, 85. https://doi.org/10.1186/s12912-020-00479-x

Zakiei, A., Khazaie, H., Rostampour, M., Lemola, S., Esmaeili, M., Dürsteler, K., … Brand, S. (2021). Acceptance and commitment therapy (ACT) improves sleep quality, experiential avoidance, and emotion regulation in individuals with insomnia-results from a randomized interventional study. *Life (Basel, Switzerland), 11*(2). https://doi.org/10.3390/life11020133

Zhang, C.-Q., Zhang, R., Lu, Y., Liu, H., Kong, S., Baker, J. S., & Zhang, H. (2021). Occupational stressors, mental health, and sleep difficulty among nurses during the COVID-19 pandemic: The mediating roles of cognitive fusion and cognitive reappraisal. *Journal of Contextual Behavioral Science, 19*, 64–71. https://doi.org/10.1016/j.jcbs.2020.12.004